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ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ»**

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МАГИСТЕРСКАЯ ДИССЕРТАЦИЯ

Усовершенствование алгоритм станции управления для автоматического запуска электроцентробежного насоса после срабатывания защит (на примере фонда скважин ОАО Томскнефть)

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Оглавление

Аннотация

Объектом исследования являются настройки и принцип действия защит СУ, которые определяют режим работы оборудования. Целью является создание алгоритма, который способен определить причину АО и предотвратить ложное срабатывание защиты, сокращая тем самым косвенные потери пластовой жидкости.

В качестве методов изучения проблемы был выбран анализ причин возникновения аномальных режимов работы системы «пласт-скважина-насос» и их моделирование. На основе закономерностей реакций определённых параметров были созданы алгоритмы действий для идентификации причин нарушения режима и методы по борьбе с ними.

Применение данных алгоритмов подразумевает использование станции управления с частотно-регулируемым приводом и станцией погружной телеметрии.

Экономический анализ показал эффективность внедрения предложенных алгоритмов за счёт сокращения в среднем 11,8 % косвенных потерь пластовой жидкости.

В качестве прогнозов рассматривается дальнейшая работа в данном направлении для создания программного продукта, способного значительно повысить степень автоматизации работы УЭЦН и принимать решения по оптимизации процессов.

Annotation

The object of the study are setting and operating principle of control station safeguard, which define the mode of operation of the equipment. The goal is to create an algorithm that is able to determine the cause of emergency shutdown and to prevent false triggering of safeguard, thereby reducing the collateral losses of the formation fluid.

Analysis of reasons of anomaly work mode of “formation-well-pump” system occurrence and modelling of these processes were chosen as a method of the problem research. Using the certain behavior of parameters at changing system conditions the algorithms were created to identify reason of regime disturbance and to take measures to struggle it.

The use of these algorithms involves exploitation of control station with variety frequency driver and submersible telemetry station.

Economic analysis has shown the effectiveness of the implementation of the proposed algorithms by reducing of 11.8% collateral losses of reservoir fluid.

As forecasts further work in this direction is considered to create a software product that can significantly increase the degree of automation of the electro-submersible pump utilization and make decisions to optimize processes.

Введение

На сегодняшний день по данным OPEC Россия – вторая страна по объёму добычи нефти и занимает 13,47 % от общего мирового объёма. Это является гарантом её стабильного и независимого развития.

С самого начала эпохи добычи ископаемых углеводородов рост нефтяной продукции достигался увеличением количества разрабатываемых месторождений. Позже, по истощении энергии пласта, необходимой для фонтанирования скважины, месторождение резервировалось. Однако нынешние реалии диктую иные условия: постоянный рост спроса на углеводородное сырьё и исчезновение «простых» для разработки месторождений привели к разработке новых «сложных» и прежде зарезервированных месторождений. Освоение таких месторождений вынудило применять новые технологии, и одной из таких является механизированный способ добычи углеводородов.

История знает огромное разнообразие механизированных способов добычи: от свабирования до использования плунжера. Однако, в виду определённых преимуществ самое большое распространение получили установки электроцентробежных насосов. Без малого 80 % нефтяной продукции в России производится с помощью УЭЦН.

Каждая скважина имеет ряд уникальных параметров, таких как глубина залегания продуктивного пласта, тип и температура флюида, коэффициент продуктивности и т.п. В то же время погружное оборудование также имеет набор индивидуальных характеристик: напорно-расходная характеристика насоса, диапазон рабочих токов и напряжений, типоразмер оборудования и т.д. Учёт всех этих особенностей для оптимальной работы оборудования и различные степени защиты для системы «пласт-скважина-насос» устанавливаются в СУ.

В мире существует огромное разнообразие СУ, отличающихся по рабочим диапазонам токов и напряжений, количеству настроек и возможности применения интеллектуальных алгоритмов. Однако все они могут быть поделены на две группы: СУ с ЧРП и СУ без ЧРП (т.н. хлопушки). Механизированный фонд ОАО «Томскнефть» ВНК на 2016 год насчитывает около 2500 скважин, где СУ с ЧРП составляет около 34 %. Отсутствие ЧРП ограничивает именно применение интеллектуальных алгоритмов управления (плавный пуск, адаптация частоты работы ПЭД, методы расклинивания, экономия электроэнергии и т.п.), однако, позволяет в определённой степени регулировать режим работы оборудования путём установки защит по многим параметрам таким, как высокое питающее напряжение, дисбаланс токов, сопротивление изоляции, температура ПЭД и т.п., тем самым предотвращая работу установки в неоптимальных диапазонах параметров.

Принцип действия таких защит имеет следующий характер: при изменении номинального (иного конкретного) значения параметра X_i в течение определённого времени t_i, задаваемого уставкой, происходит выключение УЭЦН до устранения проблемы, вызвавшей изменение рабочего параметра. Параметры X_i и t_i зависят от многих факторов (типоразмер оборудования, коэффициент продуктивности пласта, тип флюида, глубина спуска установки и т.п.) и диктуются с одной стороны заводом производителем оборудования и с другой – геологическими, технологическими и экономическими особенностями разрабатываемого месторождения, но являются статичными во времени. То есть за малым исключением не существуют алгоритмов, которые адаптировали бы текущие параметры X_i и t_i под характеристики конкретной скважины в данный период разработки.

Целью данной работы является создание интеллектуального алгоритма, который бы определял причину выходы параметров работы за допустимые пределы и вносил коррективы в настройки защит для уменьшения негативных последствий. В данном направлении, а именно, автоматизацией сбора и обработки данных для построения некоторых алгоритмов обработки событий (АО) работает ООО «Кросс-Автоматика».

Применение таких алгоритмов должно предотвращать возникновение определённых критических ситуаций (ЗСП), повышать надёжность и достоверность срабатывания защит СУ, выполнять динамическую адаптацию параметров работы оборудования ($f(Q_ж)$), уменьшая количество косвенных потерь и увеличивая межремонтный период насосного оборудования.

Одной из проблем, приводящей к косвенным потерям жидкости, является ошибочное срабатывание ЗП или ЗСП вместо защиты по повышенному и пониженному напряжению питания. В работе проанализированы методы выделения событий и предложены алгоритмы для решения данной проблемы.

3 Analysis of statistical data

First, it should be describe the meaning of the word “emergency shutdown”. ES – method of control and prevention of dangerous operational regime of equipment due to critical change of “formation-well-pump” system conditions. Modern control stations are rigged with up to 100 adjustable parameters for control, which set work regime for equipment and operational parameter range. There are large number reasons for ES. Main of them are low/high supply voltage, current misbalance, pump starvation, pump stuck, low resistivity of cable insulation etc.

To estimate size of the problem and value of solution of it, statistical analysis of ES data and run to break one for wells, where artificial lift methods are used, was performed. The date was provided by PLC “Tomskneft”. It consists of about 12500 numbers of ES during 28 months from about 2500 artificial wells of 36 different field. Run to break data was provided for last 3.4 years.

In Figure 3.1 numerical and qualitative run to break balance is shown for last 16 months. Taking the average value between two columns, the interpolating function was built. The same way the averaged function for duration of time between the nearest ES for each well independent was built too. It should be noted, that from the data the ES, which has lied to pump extraction (repairing) were excepted. Then these two averaged functions were drown for comparison of Figure 3.2.

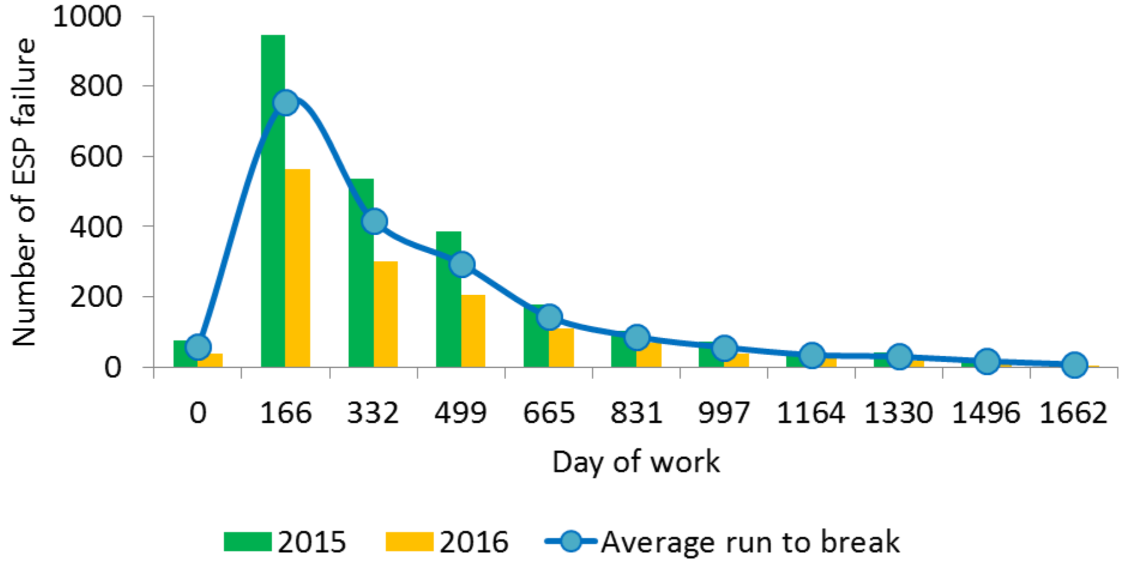

Figure 3.1 Run to break

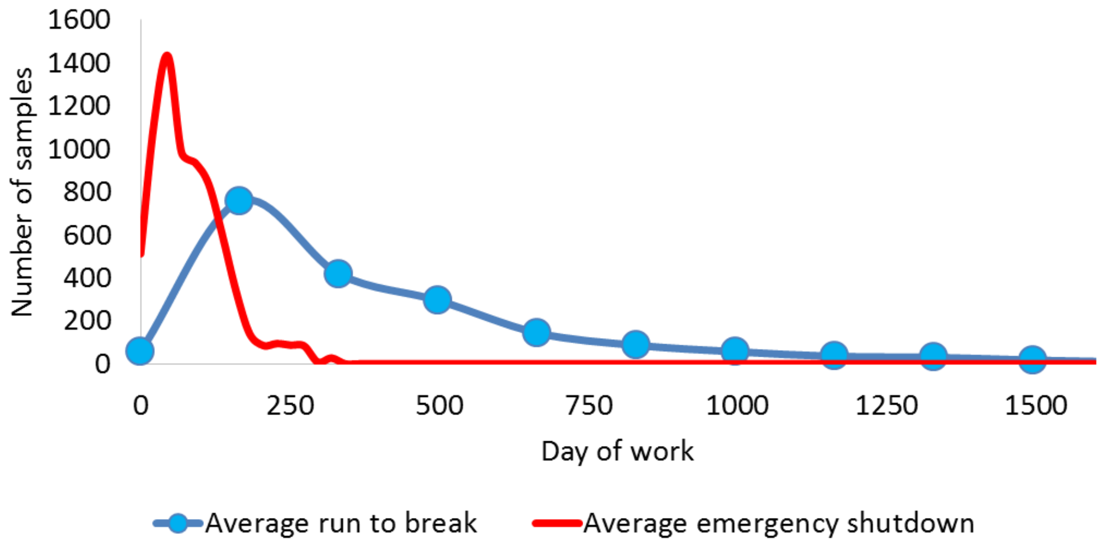

Figure 3.2 ES and RtB relationship

From the graphs, it becomes clear, that average run to break time equals approximately 315 days, when average time between the nearest ES is 36 ones. In such a manner, each pump is exposed with about 5 ES during run to break time. It means that relevant to current conditions control station setting is important process, which has significant influence on pump operation.

In “Tomskneft” company there is differentiation of formation fluid losses type caused by electricity cut (power outage) and fix efficiency of it onto direct and collateral losses (Figure 3.3). Direct losses – volume of formation fluid, that could be produced, however was not done due to absence of supply voltage in feeder line. These losses are formed during absence of electricity and time that is necessary for a well to restore volume of liquid production just before ES.

Collateral losses – losses of formation fluid that were caused due to erroneous action of safeguard or non-effective dealing of technical stuff. In other words, losses that could be prevented. Erroneous action of safeguard means action of safeguard in answer to improper condition of system. For instant, at the moment when deenergizing occurs the next situation can appear: current instantaneously exceeds error margin and control station will be saved from overload instead of be saved from low voltage. And then according to start-up sheet autoreclosing will be performed in 30-50 minutes instead of 3-5 ones, that significant increases collateral losses.

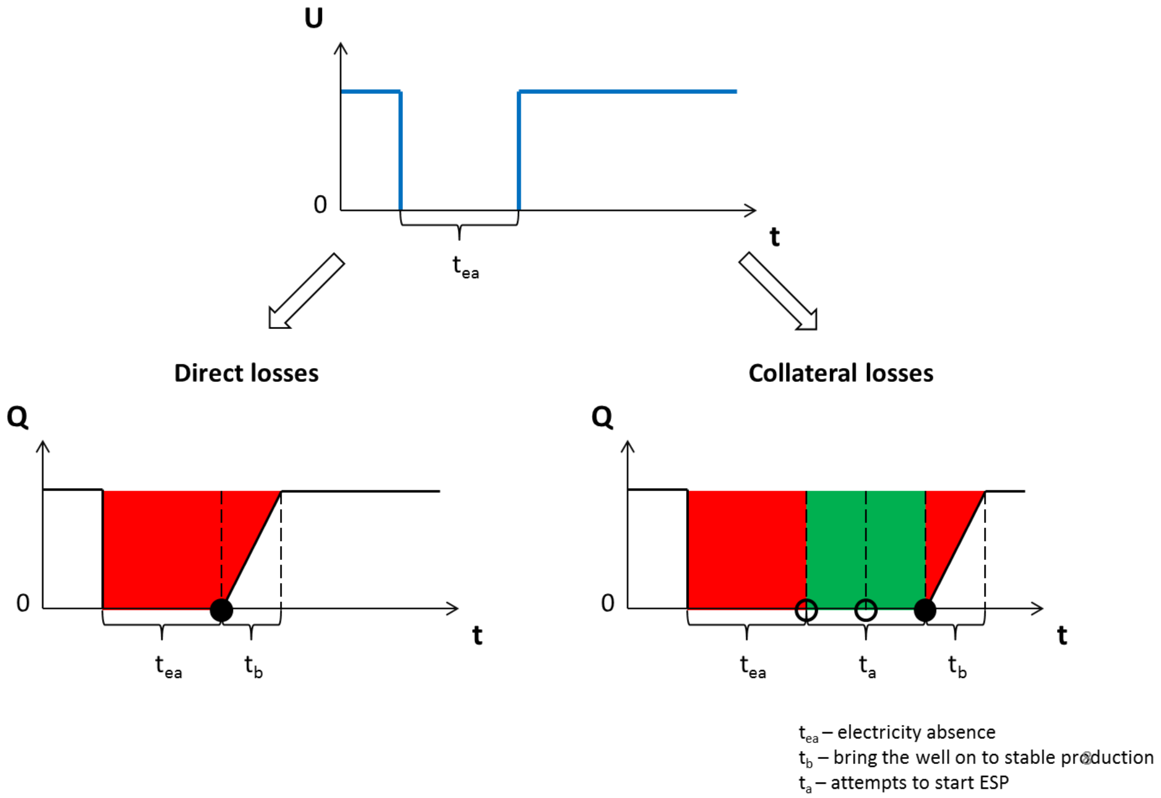

Figure 3.3 Type of losses

In Figure 3.4 numerical and qualitative direct and collateral losses are shown. It can be seen that in the summer and autumn months, the volume of losses is a multiple increase. This is due to weather conditions, namely, the emergence of thunderstorms. It is also worth noting that over time a wide range of changing the percentage of collateral losses is which means the appearance of the spontaneous nature of the ES for reasons not related to the electricity supply.

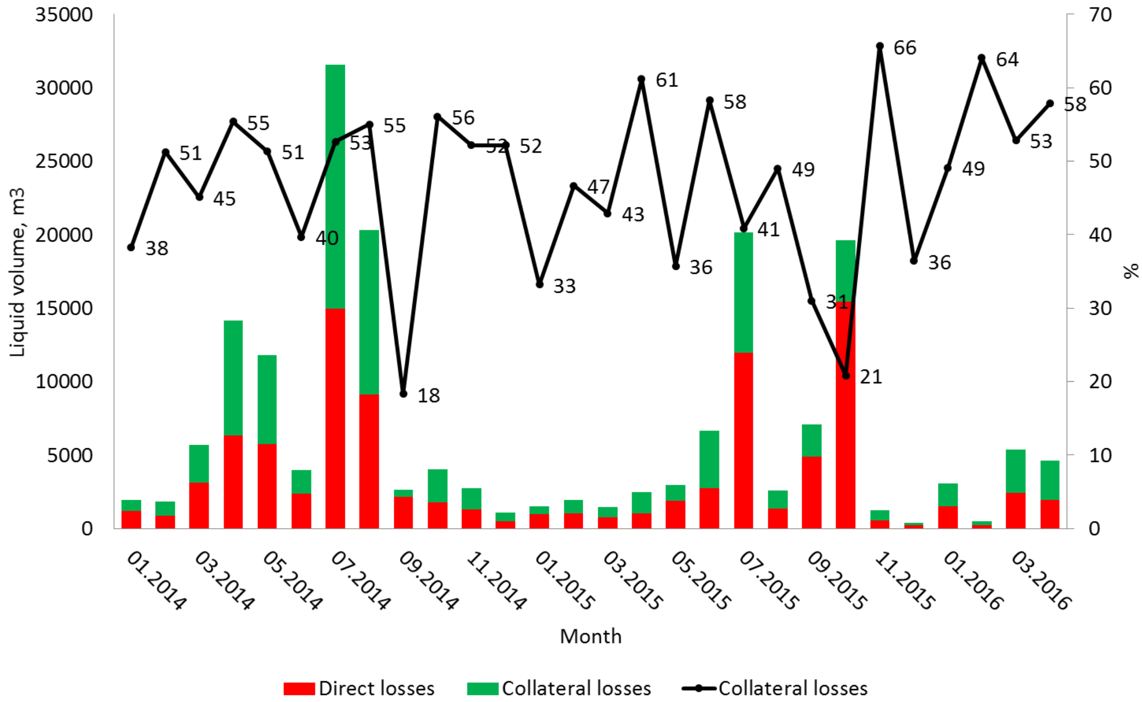

Figure 3.4 Direct and collateral losses relationship

As mentioned above, the main reason ES – power failures. However, there are other reasons. Their main groups are shown in Figure 3.5. Quantifying their characteristics and protection, the setting of which will be covered below are shown in Table 3.1.

In addition to the below there is a statistic that says that 20% of underload and 13% overload are erroneous operation of the protection to any fluctuations in the supply network: the connection / disconnection of consumers before the complete cessation of supply voltage in a working network. This leads to collateral losses, reduction of which for the given type of protection is the subject of this work. Also in the work will be reviewed and proposed methods to eliminate collateral losses arising from the turbine rotation of ESP.

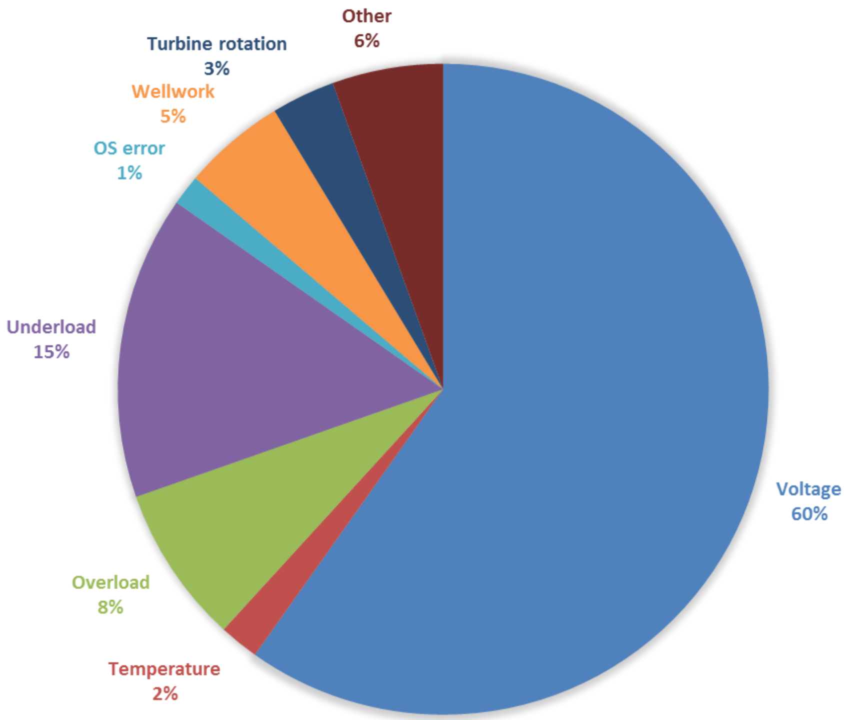

Figure 3.5 Groups of the greatest safeguards

Table 3.1 Number of safeguard actions

Safeguard	Samples	Issue
Voltage	7403	
Temperature	243	
Overload	972	*
Underload	1867	*
OS error	186	
Wellwork	632	
Turbine rotation	390	*
Other	682	

4 Facility of ESP

Installation of electrical submersible pump is divided into the downhole and ground parts. Downhole equipment consists of electrical submersible motor, protector, pump, tubing and cable. The ground part is presented with transformer substation, operator station and wellhead equipment.

4.1 Downhole equipment

The purpose of these elements of the system is to provide lift of the formation fluid to the surface.

The main element is a pump unit. It is set of stacked series consisting, in turn, a different number of rotating centrifugal impellers. Depending on the size and number of stages the special pump characteristic curve is formed showing how the amount of liquid per unit of time can be delivered to a certain height.

The next most important element of the system is the ESM. Its mission is to convert electrical energy into rotational and cause the pump to move. The main characteristics is the consumption of electricity at a certain frequency and capacity. Today, two types of ESM are used: asynchronous motor and thyratron motor, but as protection for the control station, they do not pose a significant difference, the differences in their principles of action will not be considered in this paper.

The main purpose of protector devise is to tread hydraulic separation of pump filled with formation fluid from motor filled with oil and, simultaneously, to transmit torque from the ESM to the pump. In addition, it provides free thermal expansion of oil and reduces vibration of assambly.

Power transmission from the surface on downhole to the ESM carried out by armored cable having different performance in cross-section and type of conductor, which is designed to withstand a wide range of electrical, thermal and mechanical loads.

The rise of the reservoir fluid and the suspension of pumping equipment is carried out on the tubing. The main characteristics relating to operation of the ESM there are inner diameter of the pipe, which affects the flow losses due to friction and material execution, which implies a certain duration of resistance sand and other types of mechanical and chemical strains.

Apart from the above as additional equipment installed gas separator, drain valve, check valve and telemetry system.

Gas separator is designed to reduce the volume fraction of free gas at the pump inlet to prevent the formation of gas slug and dry friction, which leads to the pump starvation and undesirable consequences in a state of equipment (overheating, wedge, burn-out of isolation).

The purpose of the check valve is to prevent the turbine rotation of the pump in case it stops, that lays reclosing of ESP until equilibration levels inside the tubing and the annulus achieves. Depending on the viscosity of the fluid reservoir, the inner diameter of the tubing and pump depth suspension, this process can take anywhere from a few seconds to an hour. It is also a problem that in wells with production rate more than 400 m^3/day check valve is not installed because of its inefficiency - in this production rate it is eroded and loses tightness with little sand production. Only the time of loss of its functionality depends on particles content.

The drain valve is installed for when it is needed to perform the extraction of the installation or to carry out well work, well test, etc. It, on the contrary, provides a drain of formation fluid from the tubing, making it easier to make the evacuation process.

Now telemetry systems allows monitoring a large amount of information: pressure at the pump inlet, motor, stator and formation fluid temperature, vibration in three axes and insulation resistance of submersible cable. Telemetry system consists of submersible portion, established as part of the assembly, and land located in the control station and designed to perform the conversion and processing of signals for further analysis.

4.2 Ground equipment

Wellhead equipment includes a wellhead housing, tubing head and Christmas tree. These components are necessary to isolate the annulus, to suspend the assembly, to control (flowmeter) and to direct the production of wells next to the account point.

The transformer station is used to directly power the control station and all downhole equipment from the AC voltage of 380 V to 6000 V. Transformers are divided into oil-filled, dry cooling, raising, etc., but this is not the theme of the work.

The vent box is the cable connection point on the surface for its decontamination and safe connection/disconnection from the control station.

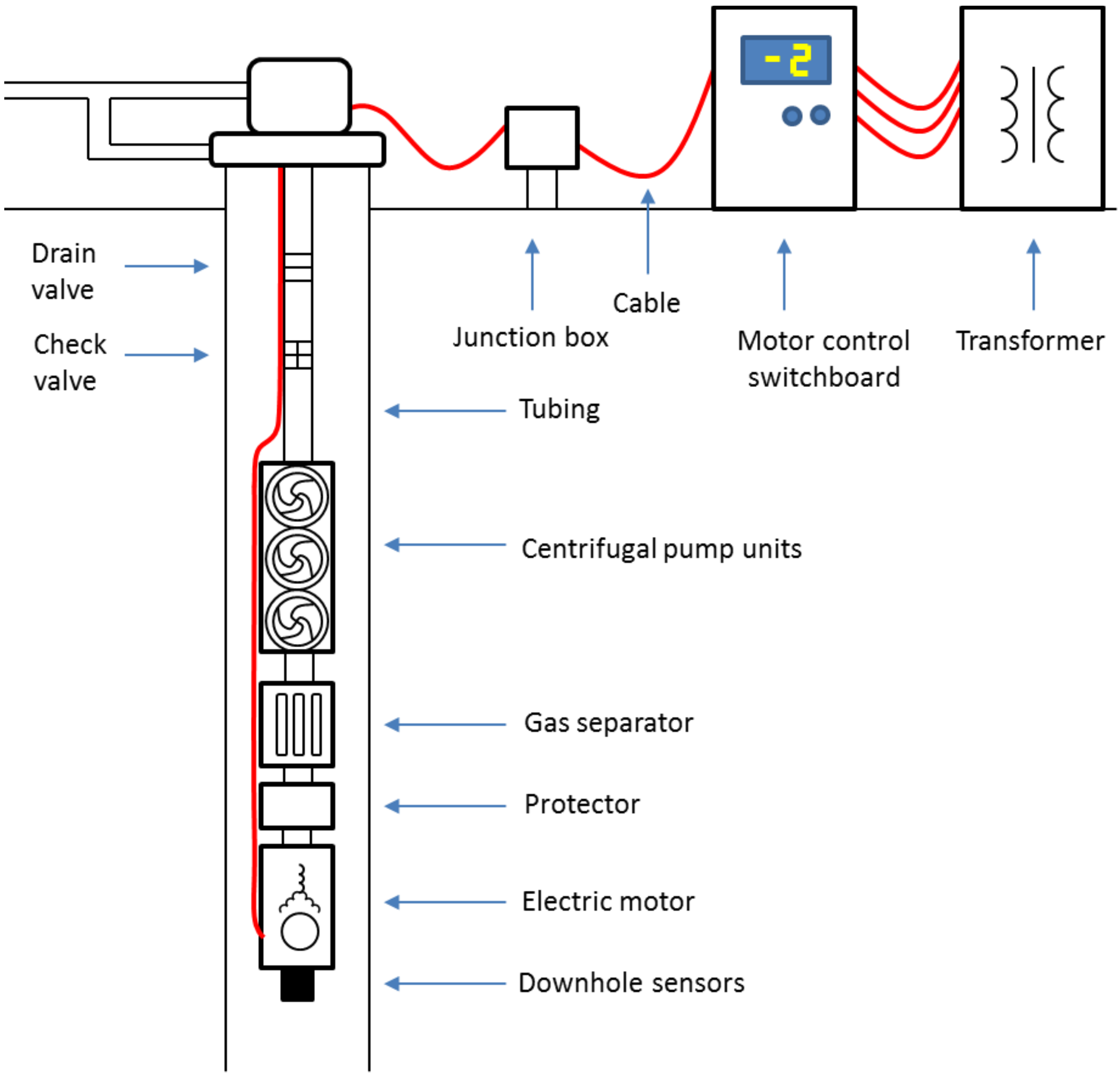

Figure 4.1 Main elements of ESP

Modern control station can solve the widest range of tasks:

- Provide ESP protection against abnormal operating conditions
- Maintaining a technological mode of a well work
- Transmit/communicate with telemetry systems
- Processing and storage of operating parameters of "formation-well-pump" system

This list is mandatory for all CS, including for so-called "Crackers" – CS of direct start. Modern CS is equipped with programmable microcontroller, which can not only remotely change settings and observe a large number of parameters, but also use sophisticated algorithms. For instance, these algorithms can be used to prevent abnormal operation modes such as pump starvation, to carry out the start of ESP while turbine rotations occurs, reducing the downtime of the well, to perform a smooth start, almost no current exceeding the nominal values, to optimize the power consumption, and more. However, these techniques are the use of local technologies for several reasons: the outdated equipment fleet of CS is not equipped with a Variable speed driver; deficient qualified of personnel; disinterest (distrust) leadership in innovative technologies.

5 Overload safeguard

5.1 Safeguard action principles

The set of input data of current setting I_{set} and runtime settings T_{set} specifies reverse ampere-second characteristic (Figure 5.1). Then overload protection work is given by:

$$\int_{0}^{T_{guard}} I_{actual}{}^{2} dt = I_{set}{}^{2} * T_{set} \qquad (5.1)$$

, where $I_{set}{}^{2} * T_{set}$ – the threshold value of the overload. If this value was exceeded then the CS powers off the ESP and expects the autoreclosing corresponding to the start-up sheet of this protection. I_{set} is set as a percentage of the nominal value.

For example, the current load current $I_{current}$ is 80% of the nominal value and the I_{set} = 100%, T_{set} = 20 seconds. In this case, the equipment is operating normally. There is a situation when the current load becomes important $I_{current}$ = 200%, then

$$T_{guard} = (I_{current} / I_{current})^{2} * T_{set} = (200/100)^{2} *20 = 5 \text{ sec.}$$

This means that at times the rated current is twice in 5 seconds, the equipment will be switched off due to pump starvation (overload) (Figure 5.1). Presented in the chart ampere-second characteristics of the equipment recommended by the manufacturer and must be adhered to when placing the setting.

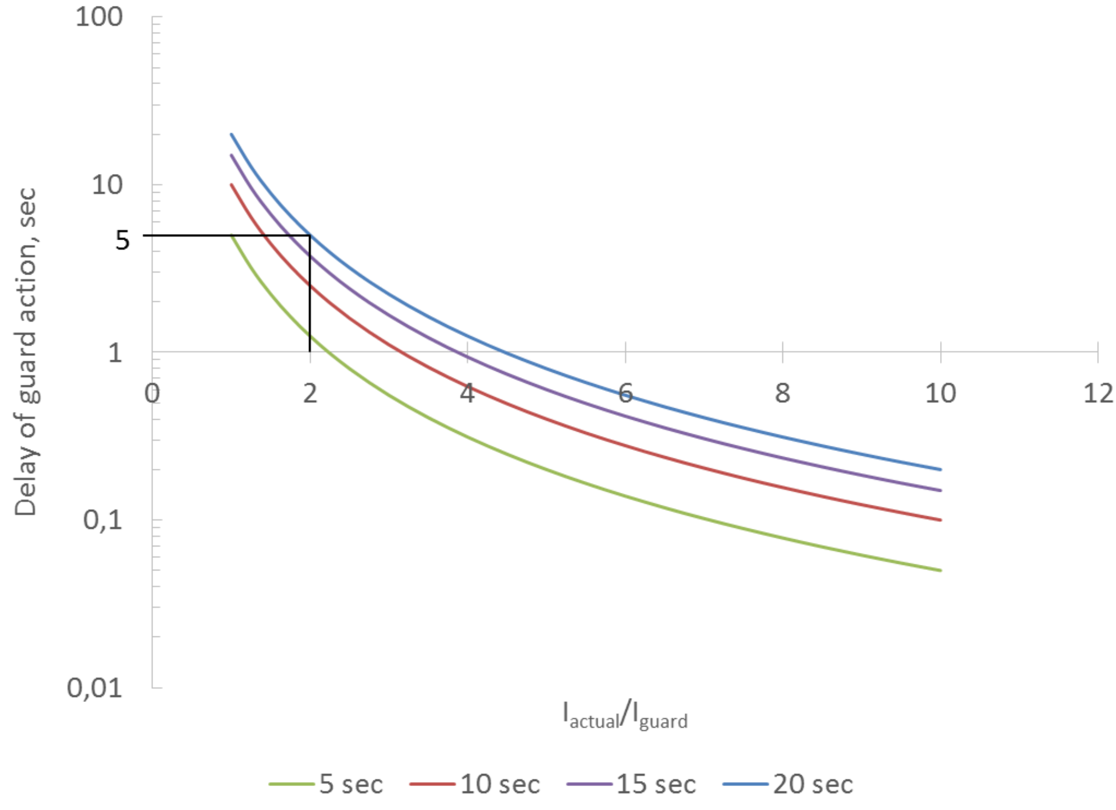

Figure 5.1 Reverse ampere-second characteristic

5.2 The cause of faults safeguard action

Supply mains on large commercial sites are always subject to unpredictable changes in the system. It is necessary to submit in advance a request for a certain type of works to power supply organization to ensure that additional capacity were connected. When the infill drilling or during welding power network experiences heavy loads at the time of connection and disconnection of powerful consumer, leading to a short (10^{-9} – 10^{2} sec) transient phenomena when the load current reaches a tenfold excess of the steady state current. Automatic protection system, designed to deal with such phenomena, installed along the power line, but in view of the complexity of their causes (even vibrations of wires between the posts in wind) cannot stabilize all voltage surge on a full scale.

There is a situation when during undervoltage preceding the blackout (optional) of power supply, there is a sharp current step (Figure 5.2). Then, if

$$\mathrm{T}_{guard}(U_{min}) > \mathrm{T}_{guard}(I_{min}) \tag{5.2}$$

, the CS will perceive the combination of these processes, such as motor overload and will expect the autoreclosing in accordance with the start-up sheet (30 minutes) instead of autoreclosing due to low voltage (5 minutes).

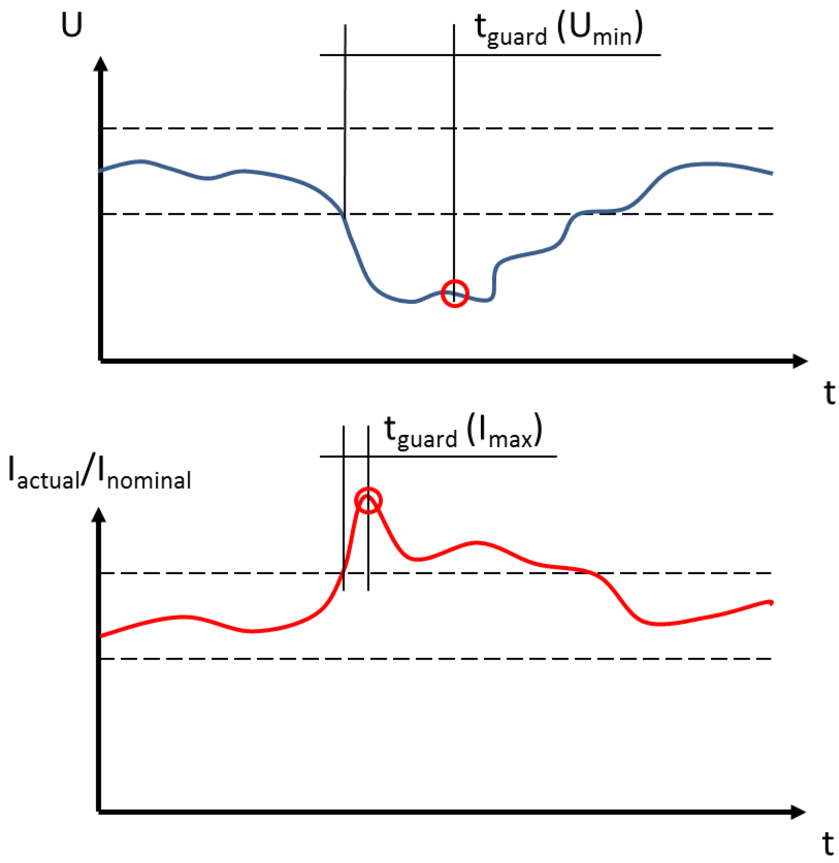

Figure 5.2 Case of erroneous overload safeguard action

5.3 The proposed algorithm for solution

First, it is needed to find the criteria that would make it possible to separate the true from the false motor overload. First, we must understand what a motor overload is.

Motor overload (pump starvation) – a phenomenon that when the amount of current consumed by the ESM is higher than the nominal value. This is because for maintaining the pump speed to a predetermined frequency the ESM must create greater torque due to increased modulus of resistance generated by friction forces.

The reason for this are rotor jams or pump stuck due to sand, scaling or corrosion of pump organs.

Thus, we need to distinguish between potential stuck of pump and voltage surge using the parameters that are independent of measurement at the time of the decision, as they are, as we discovered, are not decisive.

In Figure 5.3 the algorithm is presented, which allows using the current load of ESM, voltage and frequency of the pump trends distinguishing between the two situations described above and adjusting the equipment settings.

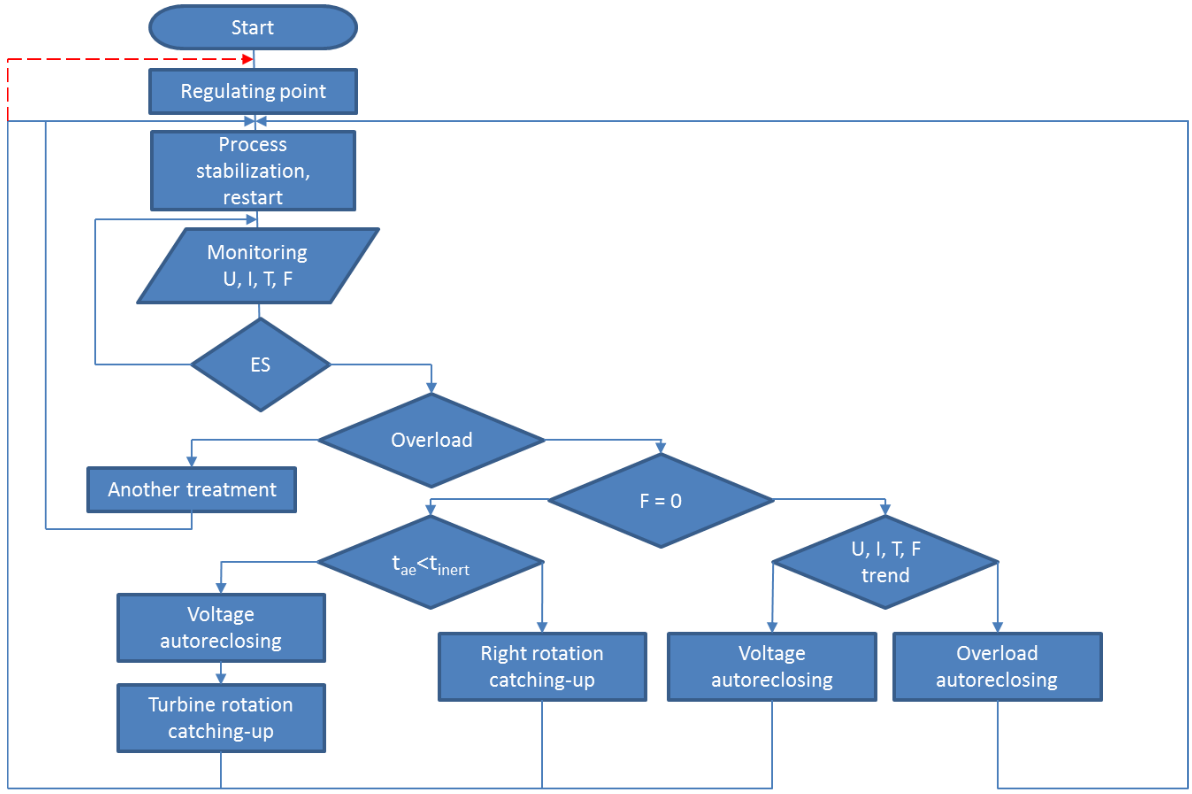

Figure 5.3 Algorithm to prevent erroneous operation of overload safeguard

After submersible and surface facilities have installed tuning settings and duration of their work occurs. Next, using the existing algorithms, the commissioning of the well at the stable mode happens, then using the telemetry parameters constant monitoring of voltage and currents in all three phases, ESM temperature and pump frequency is in operation. In the event that emergency shutdown has happened due to overvoltage, it is has to be verify whether the pump shaft is in rotation immediately after the ES.

After de-energizing CS goes to work with the so-called autonomous sources of energy and produces further measurement parameters. Moreover, CS has a certain frequency of indicator' measurement limited by the data collection and storage format.

At the same time, there is an effect of the direct inertial rotation of the pump after power failure (Figure 5.4). Duration of this process is influenced by a set of factors such as the depth of pump installation, the viscosity of the formation fluid, the inner diameter of the tubing, flow rate, etc. According to experts, up to 2 seconds of direct inertial rotation can occur.

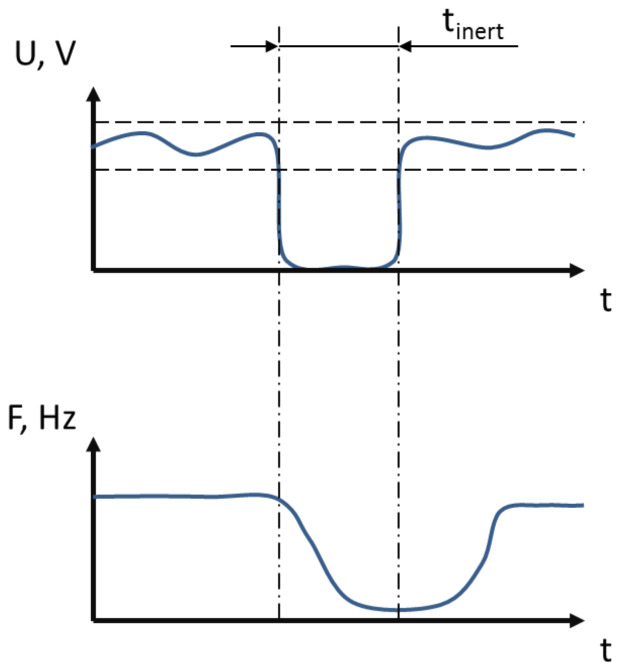

Figure 5.4 Catching-up of direct inertial rotation

Thus, if after ES has occurred direct rotation of the pump was registered and the voltage was again submitted then on the one hand we can say unequivocally that the operation of the overload safeguard was mistakenly and from another hand using the catching-up technology of direct rotation we can eliminate fluid losses.

The catching-up technology involves following procedure: determination of rotation frequency, building control equivalent frequency signal of low currents, direct catching-up of shaft rotation and acceleration of it to technological regime.

If the resumption of power supply has occurred much later than ES happened, it tells us about substantial transition process in the electricity supply mains and that it is assumed to produce the autoreclosing due to U_{min} to stabilize the parameters of current and voltage.

There are several situations where after a power failure occurs the turbine rotation is continuing: no check valve in mind design features or its fault (leakage). If the turbine rotation occurs after long power failure, then after autoreclosing due to U_{min} was taken it is necessary to use the technology catching-up of turbine rotation (Figure 5.5).

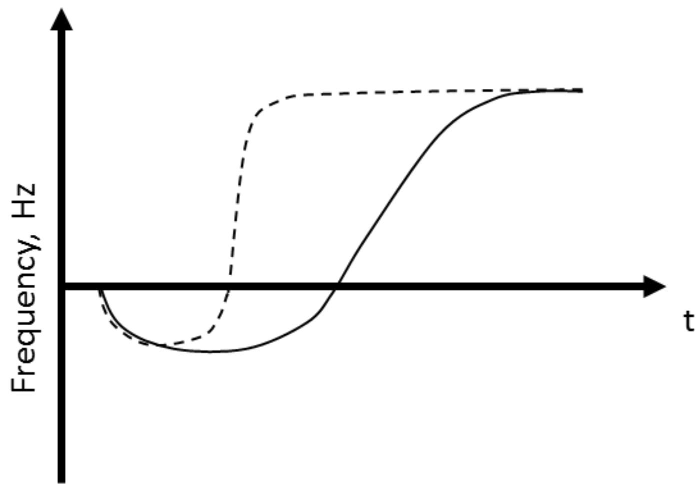

Figure 5.5 Catching-up of turbine rotation

The presented technology is not much different from the catching-up of direct rotation technology. The essence consists in also determining the rotational speed, the catching-up of rotation, deceleration and reversal of the shaft rotation. It should be noted the additional demands on the VSD: they must be able to invert the sequence of delivery of signals on phase without rebooting. A special feature here is that the deceleration and acceleration intensity depend on the size of equipment and some of the well parameters. For example, the more inert (dimensional) arrangement, the more time is needed to perform deceleration and acceleration of the pump shaft to prevent twisting.

It is also possible situation where the shaft speed rotation is zero. Then it is necessary to resort to finding trends in the history of the well operation. If trends on certain parameters have not been identified and there is no rotation of the pump, it speaks about installation of check valve and erroneous action of ES due to overload, otherwise – about true action of overload safeguard after which the appropriate autoreclosing and measures to prevent further similar cases follow.

5.4 Trend detection

The main task in solving this algorithm is to define the parameter that needs to be adjusted to prevent repetition of the situation and identify trends.

5.4.1 Adjustment of the low voltage setting

Logically, if there is an algorithm that allows distinguishing the erroneous operation of safeguard, there is no need to amend the hardware configuration. However, we should admit that the algorithm – an additional array of electronic elements, mathematical operations and logical conclusions of the high-level programming, which has a certain degree of uncertainty and reliability. It is well known, the easier the principle of unit of work, so it is more reliable. This implies that a higher priority is to amend the low-level hardware configuration, rather than re-use algorithm.

Adjusting the settings takes place after the algorithm stated false tripping. Then the algorithm assign a value of overload safeguard duration to the low voltage one:

$$\mathrm{T}_{guard}(U_{min}) = \mathrm{T}_{guard}(I_{min}) \tag{5.3}$$

Thus, the next time according to 5.1 CS will treat the event as a power surge and de-energize the ESM in 5 seconds, thereby preventing collateral loss.

Even more worst case scenario is possible, when there will be bigger current step. Then the algorithm will work and time of undervoltage setting will again be redefined and reduced square. Theoretically, taking into account the actual ampere-second characteristic and short tenfold excessing of current load the tripping time of guard can be up to 0.2 seconds. In such situations, it should refer to the electricity supplier with a complaint against a large network instability.

However, it should be noted that this principle does not account for the phenomenon when, in the case of a true overload currents will grow fewer times than were registered for the last time on the low-voltage surge. Then CS will trip after a shorter period of time than assumed at the actual current load and the equipment will be intact, but the error will be detected as a low voltage power supply instead of the overload that will prevent further efficient data processing and may harm the equipment due to inappropriate autoreclosure.

Taking into account all the above-stated arguments, it was decided not to change the setting of CS, and in each case using the proposed algorithm.

5.4.2 Trends as a criterion

As mentioned in 5.3, to identify trends in the parameters measurements taken at the moment of ES can not be used for verification. The essence of identifying trends is to find regularities of changes (in this case the combination of U, I, F, T) with time parameters under the influence of certain factors (Figure 5.6).

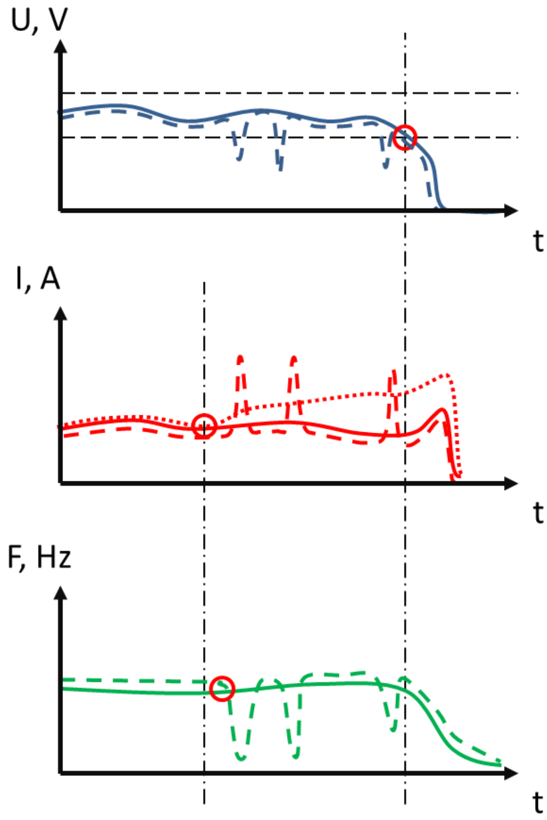

Figure 5.6 Trends to prevent erroneous overload safeguard action

When trying to identify trends it is possible to observe the three laws of change of the parameters.

It is possible when before the ES has occurred voltage, current and temperature parameters remains in the range of margin values, and the current load jumps happened only at the moment of undervoltage. This dependence of the parameters indicates erroneous operation of overload protection.

A different picture can be observed when there is a gradual deposition of solids, salts, disruption of pump stages, bearing wear and display of other phenomena that the moment of resistance forces increases, resulting in the smooth growth of current load and temperature until the ES has occurred. This combination of evidence points to the possibility of true overload of ESP.

Also, the equipment can be on the stage of deterioration that currents and temperature rise will not be tracked explicitly then, as a moment of friction force reaches such instantaneous value that can be traced brief stacking of the pump. Such moments are characterized by a short-term reduction/absence of rotation frequency, voltage drawdown and antiphase current step. It's obvious signs of predisposition of equipment to the true overload.

The big question remains, what duration, and a deviation from the nominal value considered as a trend. In other words, whether is the trend $dI / dt = 0,3$ A/day? At this stage fails to find an answer in mind the following reasons: the unique combinations of such factors as the size of pumping equipment, reservoir fluid temperature, rate of solids removal, flow rate, GOR, fluid composition, etc .; the absence of simulators that would be able to evaluate the listed dependencies. It follows that the task of identifying the characteristic behavior (trends) of the parameters due to certain changes in the system "formation-well-pump" at first falls on the technology personal who has extensive experience in the interpretation of the telemetry parameters of a particular limited number of wells.

In part, this can be solved by creating a large statistical database, where all of the above parameters and frequent measurements of particles content would be made. In addition, it would help to determine the time when the trend began to take shape that would increase the accuracy of the assessment of the latter.

Заключение

В результате выполнения данной работы было рассмотрено понятие «аварийного отключения» в целом, факторы, влияющие на причину его возникновения и последствия, вызванные этим явлением. А так же:

Был проанализирован значительный объём статистической информации, связанный с оценкой значимости определённых причин АО и их влияние на размер косвенных потерь пластовой жидкости.

Были изучены и смоделированы физические процессы, приводящие к появлению АО по таким причинам, как ЗП, ЗСП и турбинное вращение.

Основываясь на выделении закономерного поведения определённых параметров системы «пласт-скважина-насос» (трендов), были разработаны алгоритмы, способных предотвратить принятие ошибочных решений о причине возникновения и срабатывания вышеприведённых типов защит.

Предложен принцип регулирования частоты работы ЭЦН для поддержания режима работы оборудования с максимальным КПД в условиях изменения равновесия системы «пласт-скважина-насос».

Произведена оценка экономической эффективности внедрения предложенных алгоритмов на основе текущей статистики потерь углеводородов.

Определены основные факторы риска при работе с установками ЭЦН и предложены ряд действий по уменьшению травматизма и экологического вреда.

Дальнейшая работа будет заключаться в наработке экспериментальной базы закономерностей изменения рабочих параметров ограниченного количества насосов ввиду изменения параметров систем «п-с-н» на основе механизированного фонда ОАО «Томскнефть» ВНК. В рамках профессиональной деятельности предполагается тесное сотрудничество со специалистами в области энергетики, электроники и программирования для создания программного продукта, который позволил бы с высокой степенью достоверности идентифицировать критические отклонения системы, предупреждать их или принимать наиболее оптимальные решения по ликвидации последствий.

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